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Influence of NPK levels on forms of potassium under foxtail millet (*Setaria italica* L.) grown in low fertile Alfisol

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Abstract

A field experiment was conducted at Zonal Agricultural and Horticultural Research Station (ZAHRS), Shivamogga, Karnataka during the *Kharif* seasons of 2017 and 2018 to study the interaction effect of NPK levels on potassium forms and their distribution in soil under foxtail millet (*Setaria italica* L.) grown in marginal Alfisol. Eighteen treatment combinations were tried in factorial randomized block design which comprises three levels of nitrogen (0, 15 and 30 kg N ha^{-1}), two levels of phosphorus (0 and 15 kg P_2O_5 ha^{-1}) and three levels of potassium (0, 10 and 20 kg K_2O ha^{-1}). The results indicated that the readily available K fractions of soil depleted due to higher levels of NPK and in turn it replenishes from nonexchangeable-K fraction. The lattice-K was not much affected by N, P and K levels but a slight build-up of lattice-K was reported at 20 kg K_2O ha^{-1} during 2018 (652.2 mg kg^{-1}) as compared to initial year (2017 - 647.0 mg kg^{-1}). The individual levels *viz*., N_{30}, N_{15}, K_{10} and P_{15} did not influence positively and significantly reduced all K fractions during 2017 and 2018. The per cent change in available K_2O status inferred that higher requirement of potash to foxtail millet which had significantly positive response in plant systems due to increased N levels but remarkable negative balance in soil. The available potassium gets depleted in the soil up to 50% of its initial content during study of two successive cropping seasons and showed remarkable negative balance in various treatment combinations. The soils of marginal Alfisol lacking in good soil texture and K-bearing clay minerals at lower soil pH with low buffering capacity which were fails to supply the available potassium immediately.

Keywords: K depletion, K forms, marginal Alfisol, NPK levels, potassium status

Introduction

The farmers can cultivate millets with high yielding varieties but are fraught with improper nutrient management. Improper nutrient management is due to ignorance of farmers with a strong presumption that millets can come up well without supplementing nutrients through fertilizers. Cultivation of millets on marginal, inferior, low fertile/degraded lands reiterates the presumption. The above factor fuels the predicament and paves a way for low productivity of the crop. Balanced nutrition in common parlance indicates supplementing of N, P and K to the crop. So far no studies have been conducted regarding balanced potassium nutrient management in foxtail millet. In the present situation, foxtail millet is supplemented only with N and P ignoring the requirement of K. In the absence of external K application, soil K weathering is the major source for meeting the K requirement. However, rainfed Alfisols are deficient in K due to low contents of K bearing minerals in clay and silt fractions of the soil. Therefore, optimum K release from the soil to meet crop K needs is most important at critical plant growth stage of foxtail millet grown in marginal soils having poor or very low level of K. Intensive cropping, in the absence of K inputs, adversely affect K supply to crop plants and consequently crop yield (Swarup and Ganeshmurthy, 1998) [28]. Under such conditions there is higher mining of nonexchangeable-K for meeting the K requirement of crops. Hence, the knowledge about K reserve in marginal Alfisols is necessary to understand potassium nutrition and its management for a sustained crop production. In most of the intensive cropping systems in India, potassium (K) balance is negative since the additions of K seldom match the K removals resulting in larger dependence on native soil K supply from mineral reserve (Pragyan *et al*., 2017) [18].

The depletion is aggravated by the omission of K and relatively higher rates of application of only N and P under intensive production systems that generate higher demands in soils with low K-reserves such as Alfisols (Srinivasarao *et al*., 2014) [26]. These soils, with kaolinite as a dominant clay mineral and only traces of K supplying mica, are prone to severe K deficiency (Naidu *et al*. 1996) [15]. Absence of sufficient K supplementation, K removal exceeds the K input and hence the negative K balance leads to severe depletion of the K reserves. Depletion of soil K-reserves is a strong constraint to enhancing and sustaining productivity of a K-demanding crop in nonmicaceous Alfisols where both readily available as well as soil reserve K levels are low (Srinivasarao *et al*., 2014) [26]. Depletion of non-exchangeable K has also been observed in mica rich illitic alluvial soils; Inceptisols (Swarup and Chhillar 1986) [27] and smectitic Vertisols (Srinivasarao *et al*., 2000) [23].

'Potash' supplementation is crucial for the enhancement of grain yield and quality parameters. In addition, it serves as an important ion in maintaining physiological plant water relations through which it imparts tolerance to crop against drought. It also imparts tolerance against pest and diseases incidence. It is also regarded as soil aggregator through which it improves soil physical properties and consequently results in increased yields (Hamza and Anderson, 2003) [7]. The three forms of soil potassium are unavailable, slowly available or fixed and readily available or exchangeable potassium. Unavailable soil potassium is contained within the crystalline structure of micas, feldspar and clay mineral. The total potassium content in soil depends on the type of parent material and degree of mineral weathering. Where in, the availability of soil K to crops is controlled by the dynamic equilibrium among different K pools (Wang *et al*., 2004) [30] that in turn depends on rate of application and mining of K from soil system (Singh *et al*., 2009) [22]. The knowledge of various forms of K and an understanding condition controlling their availability to growing crops is an important for the appraisal of the available K in soil. This research paper is focuses on the estimation of potassium forms and its distribution under foxtail millet (*Setaria italica* L.) grown in marginal and/or low fertility soils of Alfisol as influenced by the different NPK levels.

Materials and Method

A field experiment was conducted during the *Kharif* seasons of 2017 and 2018 at Zonal Agricultural and Horticultural Research Station (ZAHRS), Shivamogga, Karnataka. Geographically the study area is situated at 13.98° N latitude and 75.57° E longitude with an altitude of 650 m above the mean sea level and comes under Southern Transitional Agro-Climatic Zone of Karnataka (Zone No. 7). Soil of experimental site was acidic (pH-5.0) belongs to *Typic Haplustepts* class with sandy loam texture. The experiment comprised three levels of nitrogen (0, 15 and 30 kg N ha^{-1}), two levels of phosphorus (0 and 15 kg P_2O_5 ha^{-1}) and three levels of potassium (0, 10 and 20 kg K_2O ha^{-1}) supplied in the form of urea, single super phosphate and muriate of potash, respectively. These NPK levels were tried in eighteen treatment combinations under factorial randomized block design with three replications. Foxtail millet (*Setaria italica* L.) was grown in marginal and/or low fertile Alfisol, where the initial available N (187.4 kg ha^{-1}), K_2O (108.7 kg ha^{-1}) were low and available P_2O_5 was medium in status (24.3 kg ha^{-1}).

The soil samples were collected after harvest of the crop and analysed for K-fractions. Water soluble-K was extracted in 1:2 soil to water suspensions (McLean, 1961) [13]. Exchangeable-K was determined by deducting water soluble-K in readily available potassium extracted with neutral 1*N* NH_4OAc at 1:5 soil to extractant ratio (Jackson, 1973) [8]. Nonexchangeable-K was determined by boiling 2.5 g of soil with 1*N* HNO_3 for 10 minutes (Knudsen *et al*., 1982) [10]. The lattice-K was obtained by difference between total potassium and sum of water soluble, exchangeable and nonexchangeable potassium. Total potassium content was determined by digesting finely ground soil (0.1g) with hydrofluoric acid (10ml) and aqua regia (2ml) in a closed vessel (Lim and Jackson, 1982) [12]. The potassium content in the various extracts was determined by calibrated flame photometer after filtration.

The data on different K forms were subjected to statistical analysis of variance (ANOVA) technique as outlined by Gomez and Gomez (1984). Testing of significance was done by 't' test at 5 per cent level of probability to determine the critical difference between the means of the two treatments wherever 'F' test was significant (Sundararaj *et al*., 1972).

Results and Discussion

Water soluble potassium

The water soluble potassium fraction Table 1 was maximum at 20 kg K_2O ha^{-1} (5.2 mg kg^{-1}) followed by 10 kg K_2O ha^{-1} (4.8 kg^{-1} each), whereas zero level of potash had significantly lower amount of water soluble-K. The water soluble-K higher at N @ 30 kg /ha (4.9 & 4.8 /kg) compared to zero level of nitrogen (4.8 & 4.7 mg /kg) and N alone @ 15 kg /ha (4.8 & 4.6 mg /kg) during 2017 and 2018, respectively. Similarly, P_2O_5 alone @ 15 kg /ha (4.8 & 4.7 mg /kg) recorded significantly lower effect on water soluble-K fraction during 2017 and 2018, respectively. While, zero level of phosphorous recorded quite higher value of WS-K fraction during 2017 (4.9 mg /kg) but, it was on par with P_{15} in 2018 (4.7 mg /kg). The experimental site was marginal land with low available K_2O status (108.7 kg /ha). The decrease in water soluble-K fraction was attributed to increased levels of nitrogen and phosphorous application. The results are in contrast with Pannu *et al*. (2002) [16] and Divya (2013) [6] reported that continuous application of FYM and NPK fertilizer enhanced the water soluble-K to a considerable extent. Superfluous

The interaction effect of water soluble potassium in soil was significantly superior at N_{30} x K_{20} (5.4 & 5.3 mg /kg) which was at par with N_{30} x P_{15} x K_{20} (5.3 mg /kg each) and P_{15} x K_{20} (5.3 mg /kg each) interactions observed during 2017 and 2018, respectively. Less positive interaction effect was exhibited at N_{15} x K_{20} (5.2 & 5.1 mg /kg) followed by N_{30} x K_{10} (4.9 mg /kg each) during 2017 and 2018, respectively. Significant and negative interaction effect on water soluble-K was observed at N_{15} x K_{10} (4.8 & 4.6 mg /kg) and N_{30} x P_{15} (4.8 & 4.6 mg /kg) than N_{15} x P_{15} and P_{15} x K_{10} interactions which have equal value of 4.8 and 4.7 mg /kg during 2017 and 2018, respectively. The increase in WS-K fraction in soil was attributed to crop response to increased levels of nitrogen and potash application. Thereby, the K concentration depleted due to higher uptake of water soluble-K by crop in consecutive of two years study period (Table 1). Similar kinds of results were reported by Brar and Singh (1995) [3], Bhandarkar (2004) [2], Sahu (2006) [19] and Arya (2008) [1].

Exchangeable potassium

The potash alone @ 20 kg /ha recorded significantly highest exchangeable-K (22.0 & 22.2 mg /kg) fraction as compared to K_2O @ 10 kg /ha (20.3 & 20.0 mg /kg), whereas zero level of potash had significantly least effect (18.9 & 18.0 mg /kg) during 2017 and 2018, respectively. The significantly lower exchangeable-K fraction was noticed at P_2O_5 alone @ 15 kg /ha (20.2 & 19.9 mg /kg) and in case of zero level, significantly higher positive effect was found (20.6 & 20.2 mg /kg) during 2017 and 2018, respectively. The exchangeable-K had significantly lower effect due to nitrogen alone @ 15 kg /ha (20.2 & 19.9 mg /kg) followed by zero level of nitrogen (20.3 & 20.2 mg /kg) whereas, N @ 30 kg /ha recorded significantly highest influence of 20.8 and 20.1 mg /kg during 2017 and 2018, respectively (Table 2). There was slightly decreasing trend in exchangeable-K at marginal soils and this was more pronounced in the first year than later crop taken in succession. Crops started removing K from non-exchangeable fractions after a substantial part of exchangeable-K exhausted as per observation made by Patiram and Prasad, 1984 [17]; Chakravarthi and Patnaik, 1990 [5].

The interaction of P_{15} x K_{20} was found to have significantly highest positive influence on exchangeable potassium fraction (22.3 mg /kg each) followed by N_{15} x K_{20}, (21.8 & 22.2 mg /kg) during 2017 and 2018, respectively (Table 2). Less positive interaction effect on exchangeable-K fraction was resulted at N_{30} x K_{20} (22.5 & 21.7 mg /kg) and N_{30} x P_{15} x K_{20} (22.3 & 21.0 mg /kg) as compared to N_{15} x K_{10} (20.4 & 20.5 mg /kg) and N_{15} x P_{15} (20.3 & 20.1 mg /kg) interaction during 2017 and 2018, respectively. Similarly, negative interaction effect was significantly produced at N_{30} x P_{15} (20.0 & 19.2 mg /kg) and P_{15} x K_{10} (20.0 & 19.8 mg /kg) than N_{30} x K_{10} (20.5 & 19.9 mg /kg) during 2017 and 2018, respectively. This was attributed to crop response by increased levels of nitrogen and potash application and thereby depleting its concentration in soil due to higher uptake of exchangeable-K content under foxtail millet grown in marginal soils. It was continuously replenished by the non-exchangeable fraction and in turn it replenishes the potassium in soil solution. It was readily exchanged with other cations and readily available to plants. The results of this study are in conformity with those reported by Brar and Singh (1995) [3], Bhandarkar (2004) [2], Sahu (2006) [19] and Arya (2008) [1].

Available potassium

Depletion of potash in the experimental site was the reason for lower potassium status. The small difference in the clay mineralogy of the soils appears to be crucial to the fate of applied K and possibly explains the contrasting soil K-dynamics (Carter and Singh, 2004) [4]. The available potassium gets depleted in the soil after harvest of first and second crops while increase in N and phosphorous levels. The per cent change in available potassium status of post-harvest soil of foxtail millet was presented in Fig. 1 compared to zero level of N, P and K during 2017 and 2018. It represented that difference in per cent change over individual levels of N, P_2O_5 and K_2O and it helped to know the extent of possible depletion in available potassium status in soil (Srinivasarao *et al*., 2011) [25]. The change in available potassium status diminished up to 50% due to application of 30 kg N /ha which had significantly highest reduction among the nitrogen and phosphorous levels. But application of K levels had positively increased available K_2O status from 10 to 20% (@ 20 kg /ha) even though it was not compensating for optimum requirement of foxtail millet. The total K-uptake pattern inferred that higher requirement of potash to foxtail millet (data on K-uptake not included here) due to increased N levels had significantly positive interaction on plant uptake and negative impact on available potash in soil system. The results are in agreement with the findings of Srinivasarao *et al*. (2010) [24] under groundnut grown on Alfisols at Anantapur, India.

The results of available potassium status in soil during the investigation periods evidenced similar kind of results at different N x P x K treatment combinations were depicted in Fig. 2 compared to absolute control. The available potassium gets depleted in the soil up to 50% of its initial content during study of two successive cropping seasons and showed remarkable negative balance in various treatment combinations. The increased N levels have been pronounced significantly higher rate of changes in available K_2O during 2018 as compared to initial year of investigation (2017). Thereby, the K concentration depleted readily available-K in consecutive of two years study period. The potassium content and its uptake by straw and grain of foxtail millet were largely contributed from available form of potassium in soil. Similar findings are observed by Kadrekar (1976) [9].

Non-exchangeable potassium

The nonexchangeable potassium or fixed potassium differs from mineral potash in that it is not bonded within the crystal structures of soil mineral particles. The potash alone @ 20 kg /ha recorded significantly superior influence on nonexchangeable-K (53.9 & 49.4 mg /kg) fraction as compared to K_{10} (49.6 & 45.1 mg /kg) and zero level of potash which was low response (46.1 & 41.0 mg /kg) during 2017 and 2018, respectively. The nonexchangeable-K fraction in soil was significantly less positive at P_{15} (49.3 & 45.0 mg /kg) as compared to zero level (P_0) (50.3 & 45.3 mg /kg) during 2017 and 2018, respectively. Among nitrogen levels, 30 kg N /ha has got significantly superior over other N levels revealed well positive response on nonexchangeable-K (50.9 & 45.6 mg /kg) fraction during 2017 and 2018, respectively (Table 3). But, significantly low positive effect was noticed at zero level of nitrogen (49.2 & 44.9 mg /kg) followed by application of 15 kg N /ha (49.4 & 45.0 mg /kg). The lower amount of nonexchangeable-K might be due to release of fixed-K to compensate the removal of water soluble and exchangeable-K by plants and leaching losses (Divya, 2013) [6]. This indicated that the fraction of nonexchangeable-K is most important in plant nutrition which has a decreased trend with continuous cropping at marginal soils. The results are in conformity with Tiwari (1985) [29] in Alluvial soils and Srinivasarao *et al*. (2010) [24] on Alfisols at Anantapur, India.

Among N x P interactions, N_{30} x P_0 (50.3 mg /kg) was found to be significantly highest during 2017, whereas N_{30} x P_{15} has significantly negative influence on nonexchangeable-K (45.9 mg /kg) fraction during 2018. It was significantly less at N_{15} x P_0 (49.1 & 44.1 mg /kg) during 2017 and 2018, respectively. Among P x K interactions, the nonexchangeable-K was significantly highest at P_{15} x K_{20} (54.5 & 50.3 mg /kg) which was superior and least effect observed in P_{15} x K_0 (44.6 & 40.4 mg /kg) during 2017 and 2018, respectively. Similarly, among N x K interactions, nonexchangeable-K fraction have been responded significantly maximum at N_{30} x K_{20} (55.1 & 49.3 mg /kg) whereas, N_{15} x K_0 (45.3 & 39.4 mg /kg) has exhibited least effect during 2017 and 2018, respectively. The similar trend on nonexchangeable-K fraction was evidenced significantly superior at N_{15} x P_{15} x K_{20} (T_{12}) treatment (55.3

& 51.5 mg /kg) and lesser at N_{15} x K_0 during 2017 (at P_{15} - 44.1 mg /kg) and 2018 (at P_0 - 38.9 mg /kg) over the other treatment combinations depicted in Table 3.

Nonexchangeable-K showed decreasing trend and was least in application of higher levels of N and P fertilizers. The crop response to increased levels of nitrogen and phosphorus leading to increased uptake of exchangeable-K leaving lesser amount in soil. These findings are in agreement with Santhy *et al.* (2003) [20]. As indicated earlier, the experimental site was marginal land with light textured clay mineral *i.e.* low fertile Alfisols. Hence, the marked decrease in nonexchangeable-K fraction. Similar results were obtained by Singh *et al.* (2002) [21] where continuous cropping of fifteen years depleted available-K in soil.

Lattice potassium

The lattice-K fraction was indicated significant and negative influence at N alone @ 30 kg /ha (612.7 & 594.7 mg /kg) followed by 15 kg N /ha (638.9 & 631.1 mg /kg) whereas, zero level (663.7 & 657.5 mg /kg) showed significantly higher influence during 2017 and 2018, respectively. K_2O level @ 20 kg /ha noticed significantly maximum positive influence on lattice-K (647.0 & 652.2 mg /kg) fraction as compared to K_2O @ 10 kg /ha (640.7 & 638.2 mg /kg), but zero level potash (627.5 & 592.9 mg /kg) had less effect during 2017 and 2018, respectively. Similarly, P_2O_5 alone @ 15 kg /ha was resulted significant and positive effect on lattice-K with a value of 678.7 and 665.7 mg /kg while, zero level P_2O_5 shown negative effect (598.2 & 589.9 mg /kg) during 2017 and 2018, respectively. The lattice-K was not much affected by N, P and K levels but a slight build-up of lattice-K was reported at potash alone @ 20 kg /ha application during 2018 (652.2 mg /kg) as compared to initial year (2017 - 647.0 mg /kg) (Table 4). In contrast to the K_{20}, the other individual levels like N_{30}, N_{15}, K_{10} and P_{15} did not influence positively and significantly reduced its concentration in soil during 2018 with the combined application of K-fertilizer.

P_2O_5 @ 15 kg + K_2O @ 20 kg /ha (P_{15} x K_{20}) interaction was found to have higher positive influence on lattice-K (686.8 & 692.4 mg /kg) followed by P_{15} x K_{10} (680.5 & 677.5 mg /kg) during 2017 and 2018, respectively. But, the interactions of P x K did not differed significantly during 2017 and it was significantly differed during 2018. Less positive effect on lattice-K showed at N_{30} x P_{15} x K_{20} (665.2 & 665.1 mg /kg) followed by N_{15} x P_{15} (674.9 & 661.0 mg /kg) during 2017 and 2018, respectively. Significant and negative response was seen at higher levels of N fertilizer interactions with potash such as N_{30} x K_{10} (614.3 & 605.9 mg /kg) and N_{30} x K_{20} (621.4 & 620.9 mg /kg) compared to N_{30} x P_{15} (659.8 & 640.5 mg /kg), N_{15} x K_{20} (646.2 & 654.0 mg /kg) and N_{15} x K_{10} interactions (640.7 & 644.9 mg /kg) during 2017 and 2018, respectively. In contrast to P_{15} x K_{20} interaction, the other interactions such as P_{15} x K_{10}, N_{30} x P_{15} x K_{10}, N_{15} x P_{15}, N_{30} x P_{15}, N_{15} x K_{20}, N_{15} x K_{10}, N_{30} x K_{20} and N_{30} x K_{10} did not influence positively and significantly depletes lattice-K fraction during 2018 even though high level potash application (20 kg /ha) as compared to 2017 season (Table 4). The similar trend on lattice-K fraction was also observed significantly highest positive influence at N_0 x P_{15} x K_{20} (T_6- 714.5 & 730.3 mg /kg) treatment combination and lowest was described at N_{30} x P_0 x K_0 (T_{13}-554.0 & 519.8 mg /kg) over the other treatment combinations during 2017 and 2018, respectively.

This form of potash is distinct from mineral potassium; it is not bonded covalently within the crystal structure of clay minerals. The lattice-K is made available to plants by weathering and the amount released depends upon in the soil texture and environmental conditions (Lalitha and Dhakshinamoorthy, 2014) [11]. The result of lattice-K fraction was in contrast to the findings of Mukhopadhyay and Datta (2001) where, the higher presence of lattice-K could be because the soils are rich in K-bearing minerals. The release and fixation of the lattice-K is mainly governed by the type of clay minerals, soil reaction, type of cation *etc*. It's liberation allowing entry into soil solution with weathering of these minerals and the formation of new mineral structures such as clay minerals, oxides and hydroxides. These results are according to findings of Arya (2008) [1].

Total potassium

The nitrogen alone @ 30 kg /ha recorded significant and lower effect on total-K (689.3 & 671.0 mg /kg) content followed by 15 kg N /ha (713.2 & 710.3 mg /kg), while zero level of N had significantly positive influence on total-K (738.4 & 744.9 mg /kg) content of soil during 2017 and 2018, respectively. It was significantly less effect at zero level of potash (697.3 & 669.7 mg /kg) during 2017 and 2018, respectively. The total-K content was observed significantly maximum positive effect at 20 kg K_2O /ha (728.3 & 738.5 mg /kg) as compared to K_2O alone @ 10 kg /ha (715.3 & 718.0 mg /kg). Similarly, significant and higher positive effect on total-K content was noticed at application of 15 kg P_2O_5 /ha (753.2 & 745.8 mg /kg) whereas zero level of P_2O_5 had significantly negative effect (674.0 & 671.7 mg /kg) during 2017 and 2018, respectively. Contradictory to the K_{20} and K_{10} levels, the N_{15}, N_{30} and P_{15} levels have shown that significantly negative effect on total-K content in soil during succeeded crop of 2018 compared to initial year of investigation (Table 5). The negative-K balance after second crop cycle indicates that crop removal exceeds the potash application up to 55.0 kg K_2O /ha. The decreasing trends in this form at intensive cropping system in a marginal/ infertile Alfisol have also been reported by many workers like Srinivasarao *et al*. (2014) [26] and Sahu (2006) [19].

The interaction of N_{30} x K_{10} was found significant and negative influence on total-K (689.9 & 681.3 mg /kg) content followed by N_{30} x K_{20} (704.4 & 702.6 mg /kg) during 2017 and 2018, respectively. Significant and positive response on total-K was produced at P_{15} x K_{20} (769.1 & 780.6 mg /kg) and P_{15} x K_{10} (754.2 & 757.3 mg /kg) interactions in soils of study area during 2017 and 2018, respectively. The interaction effects on total-K content was revealed significantly less positive in the descending order at N_{15} x P_{15} > N_{30} x P_{15} x K_{20} > N_{30} x P_{15} > N_{15} x K_{20} > N_{15} x K_{10} during 2017 and N_{30} x P_{15} x K_{20} > N_{15} x P_{15} > N_{15} x K_{20} > N_{15} x K_{10} > N_{30} x P_{15} during 2018. But, it was responded significantly very well at N_0 x P_{15} x K_{20} (T_6 - 796.0 & 827.0 mg /kg) combination and less was described at N_{30} x P_0 x K_0 (T_{13} - 629.1 & 593.9 mg /kg) over the other treatment combinations during 2017 and 2018, respectively (Table 5). Contradictory to P_{15} x K_{20} and P_{15} x K_{10} interactions, the other interactions includes N x P, N x K and N x P x K combinations were differed significantly negative effect on total-K content during succeeded crop (2018) as compared to initial year of investigation. This was attributed due to more pronounced growth and development of foxtail millet and led to higher uptake of potash, since the crop was grown on marginal and low buffered soils absolutely less response to present level of potash nutrition. Low status of these fractions in infertile/marginal Alfisol attributed to the depletion of potassium by crop removal which resulted to significant reduction in potassium nutrition in the due course of time (Divya, 2013) [6].

Table 1: Water soluble potassium (mg /kg) in post-harvest soil of foxtail millet as influenced by NPK levels during 2017 and 2018

Treatments		**2017**					**2018**				
		Potassium levels			**Mean of N x P**	**Mean of N**	**Potassium levels**			**Mean of N x P**	**Mean of N**
N-levels	**P-levels**	**K_0**	**K_{10}**	**K_{20}**			**K_0**	**K_{10}**	**K_{20}**		
N_0	P_0	4.6	4.7	5.1	4.8	4.8	4.1	4.7	5.2	4.7	4.7
	P_{15}	4.5	4.8	5.3	4.8		4.1	4.9	5.2	4.7	
Mean of No x K		4.5	4.8	5.2			4.1	4.8	5.2		
N_{15}	P_0	4.5	4.8	5.0	4.8	4.8	4.2	4.5	4.7	4.5	4.6
	P_{15}	4.3	4.8	5.4	4.8		4.0	4.7	5.5	4.7	
Mean of N_{15} x K		4.4	4.8	5.2			4.1	4.6	5.1		
N_{30}	P_0	4.8	5.1	5.4	5.1	4.9	4.5	5.1	5.4	5.0	4.8
	P_{15}	4.4	4.6	5.3	4.8		4.0	4.6	5.3	4.6	
Mean of N_{30} x K		4.6	4.9	5.4			4.3	4.9	5.3		
Mean of P_0		4.6	4.9	5.2	4.9		4.3	4.8	5.1	4.7	
Mean of P_{15}		4.4	4.8	5.3	4.8		4.0	4.7	5.3	4.7	
Mean of K		4.5	4.8	5.2			4.2	4.8	5.2		
Sources		S.Em ±			CD (P = 0.05)		S.Em ±			CD (P = 0.05)	
Nitrogen (N)		0.004			0.010		0.004			0.010	
Phosphorus (P)		0.003			0.009		0.003			0.009	
Potash (K)		0.004			0.010		0.004			0.010	
N x K		0.006			0.018		0.006			0.018	
K x P		0.005			0.015		0.005			0.015	
N x P		0.005			0.015		0.005			0.015	
N x P x K		0.009			0.026		0.009			0.026	

Table 2: Exchangeable potassium (mg /kg) in post-harvest soil of foxtail millet as influenced by NPK levels during 2017 and 2018

Treatments		**2017**					**2018**				
		Potassium levels			**Mean of N x P**	**Mean of N**	**Potassium levels**			**Mean of N x P**	**Mean of N**
N-levels	**P-levels**	**K_0**	**K_{10}**	**K_{20}**			**K_0**	**K_{10}**	**K_{20}**		
N_0	P_0	19.1	19.9	21.5	20.1	20.3	18.5	19.0	22.2	19.9	20.2
	P_{15}	18.7	20.3	22.1	20.4		18.1	20.1	23.0	20.4	
Mean of No x K		18.9	20.1	21.8			18.3	19.6	22.6		
N_{15}	P_0	19.0	20.5	21.1	20.2	20.2	17.2	20.4	21.4	19.7	19.9
	P_{15}	18.0	20.3	22.6	20.3		16.8	20.6	23.0	20.1	
Mean of N_{15} x K		18.5	20.4	21.8			17.0	20.5	22.2		
N_{30}	P_0	20.4	21.6	22.7	21.6	20.8	19.6	20.9	22.4	21.0	20.1
	P_{15}	18.3	19.5	22.3	20.0		17.9	18.8	21.0	19.2	
Mean of N_{30} x K		19.3	20.5	22.5			18.7	19.9	21.7		
Mean of P_0		19.5	20.6	21.7	20.6		18.4	20.1	22.0	20.2	
Mean of P_{15}		18.3	20.0	22.3	20.2		17.6	19.8	22.3	19.9	
Mean of K		18.9	20.3	22.0			18.0	20.0	22.2		
Sources		S.Em ±			CD (P = 0.05)		S.Em ±			CD (P = 0.05)	
Nitrogen (N)		0.02			0.04		0.02			0.04	
Phosphorus (P)		0.01			0.04		0.01			0.04	
Potash (K)		0.02			0.04		0.02			0.04	
N x K		0.03			0.08		0.03			0.08	
K x P		0.02			0.06		0.02			0.06	
N x P		0.02			0.06		0.02			0.06	
N x P x K		0.04			0.11		0.04			0.11	

Table 3: Nonexchangeable potassium (mg /kg) in post-harvest soil of foxtail millet as influenced by NPK levels during 2017 and 2018

Treatments		**2017**					**2018**				
		Potassium levels			**Mean of N x P**	**Mean of N**	**Potassium levels**			**Mean of N x P**	**Mean of N**
N-levels	**P-levels**	**K_0**	**K_{10}**	**K_{20}**			**K_0**	**K_{10}**	**K_{20}**		
N_0	P_0	46.2	48.6	52.5	49.1	49.2	41.1	45.5	48.6	45.1	44.9
	P_{15}	45.0	49.4	53.7	49.4		39.8	44.4	49.9	44.7	
Mean of No x K		45.6	49.0	53.1			40.5	45.0	49.3		
N_{15}	P_0	46.6	49.1	51.5	49.1	49.4	38.9	45.4	48.0	44.1	45.0
	P_{15}	44.1	49.6	55.3	49.7		39.9	46.1	51.5	45.9	
Mean of N_{15} x K		45.3	49.3	53.4			39.4	45.8	49.8		
N_{30}	P_0	49.9	52.8	55.7	52.8	50.9	44.9	46.1	48.9	46.6	45.6
	P_{15}	44.8	47.6	54.6	49.0		41.4	42.9	49.3	44.6	
Mean of N_{30} x K		47.3	50.2	55.1			43.2	44.5	49.1		
Mean of P_0		47.6	50.1	53.2	50.3		41.7	45.7	48.5	45.3	
Mean of P_{15}		44.6	48.9	54.5	49.3		40.4	44.5	50.3	45.0	
Mean of K		46.1	49.5	53.9			41.0	45.1	49.4		
Sources		S.Em ±			CD (P = 0.05)		S.Em ±			CD (P = 0.05)	

Nitrogen (N)	0.04	0.11	0.04	0.11
Phosphorus (P)	0.03	0.09	0.03	0.09
Potash (K)	0.04	0.11	0.04	0.11
N x K	0.06	0.19	0.06	0.19
K x P	0.05	0.15	0.05	0.15
N x P	0.05	0.15	0.05	0.15
N x P x K	0.09	0.26	0.09	0.26

Table 4: Lattice potassium content (mg /kg) in post-harvest soil of foxtail millet as influenced by NPK levels during 2017 and 2018

Treatments		**2017**					**2018**				
		Potassium levels			**Mean of N x P**	**Mean of N**	**Potassium levels**			**Mean of N x P**	**Mean of N**
N-levels	**P-levels**	**K_0**	**K_{10}**	**K_{20}**			**K_0**	**K_{10}**	**K_{20}**		
N_0	P_0	612.9	633.5	632.4	626.2	663.7	596.0	629.3	633.1	619.5	657.5
	P_{15}	688.3	700.8	714.5	701.2		657.9	698.7	730.3	695.6	
Mean of No x K		650.6	667.1	673.4			627.0	664.0	681.7		
N_{15}	P_0	592.0	604.4	611.8	602.8	638.9	560.0	617.4	626.3	601.2	631.1
	P_{15}	667.4	676.9	680.6	674.9		628.9	672.4	681.8	661.0	
Mean of N_{15} x K		629.7	640.7	646.2			594.4	644.9	654.0		
N_{30}	P_0	554.0	564.9	577.5	565.5	612.7	519.8	550.4	576.7	549.0	594.7
	P_{15}	650.5	663.7	665.2	659.8		594.9	661.3	665.1	640.5	
Mean of N_{30} x K		602.3	614.3	621.4			557.4	605.9	620.9		
Mean of P_0		586.3	600.9	607.2	598.2		558.6	599.0	612.0	589.9	
Mean of P_{15}		668.7	680.5	686.8	678.7		627.3	677.5	692.4	665.7	
Mean of K		627.5	640.7	647.0			592.9	638.2	652.2		
Sources		S.Em ±			CD (P = 0.05)		S.Em ±			CD (P = 0.05)	
Nitrogen (N)		0.49			1.41		0.49			1.41	
Phosphorus (P)		0.40			1.15		0.40			1.15	
Potash (K)		0.49			1.41		0.49			1.41	
N x K		0.85			2.44		0.85			2.44	
K x P		0.69			NS*		0.69			1.99	
N x P		0.69			1.99		0.69			1.99	
N x P x K		1.20			3.45		1.20			3.45	

NS* = Non significant

Table 5: Total potassium content (mg /kg) in post-harvest soil of foxtail millet as influenced by NPK levels during 2017 and 2018

Treatments		**2017**					**2018**				
		Potassium levels			**Mean of N x P**	**Mean of N**	**Potassium levels**			**Mean of N x P**	**Mean of N**
N-levels	P-levels	K_0	K_{10}	K_{20}			K_0	K_{10}	K_{20}		
N_0	P_0	683.4	706.6	711.5	700.5	738.4	681.5	714.3	723.2	706.3	744.9
	P_{15}	757.2	775.6	796.0	776.3		737.0	786.2	827.0	783.4	
Mean of No x K		720.3	741.1	753.7			709.3	750.3	775.1		
N_{15}	P_0	662.2	678.3	689.4	676.6	713.2	645.0	694.1	706.8	682.0	710.3
	P_{15}	733.8	751.6	763.9	749.7		696.5	751.0	768.6	738.7	
Mean of N_{15} x K		698.0	715.0	726.6			670.7	722.5	737.7		
N_{30}	P_0	629.1	644.4	661.3	645.0	689.3	593.9	627.8	658.9	626.9	671.0
	P_{15}	718.0	735.4	747.5	733.6		664.6	734.8	746.2	715.2	
Mean of N_{30} x K		673.5	689.9	704.4			629.2	681.3	702.6		
Mean of P_0		658.2	676.4	687.4	674.0		640.1	678.8	696.3	671.7	
Mean of P_{15}		736.3	754.2	769.1	753.2		699.3	757.3	780.6	745.8	
Mean of K		697.3	715.3	728.3			669.7	718.0	738.5		
Sources		S.Em ±			CD (P = 0.05)		S.Em ±				CD (P = 0.05)
Nitrogen (N)		0.49			1.41		0.49				1.41
Phosphorus (P)		0.40			1.15		0.40				1.15
Potash (K)		0.49			1.41		0.49				1.41
N x K		0.85			2.44		0.85				2.44
K x P		0.69			1.99		0.69				1.99
N x P		0.69			1.99		0.69				1.99
N x P x K		1.20			3.45		1.20				3.45

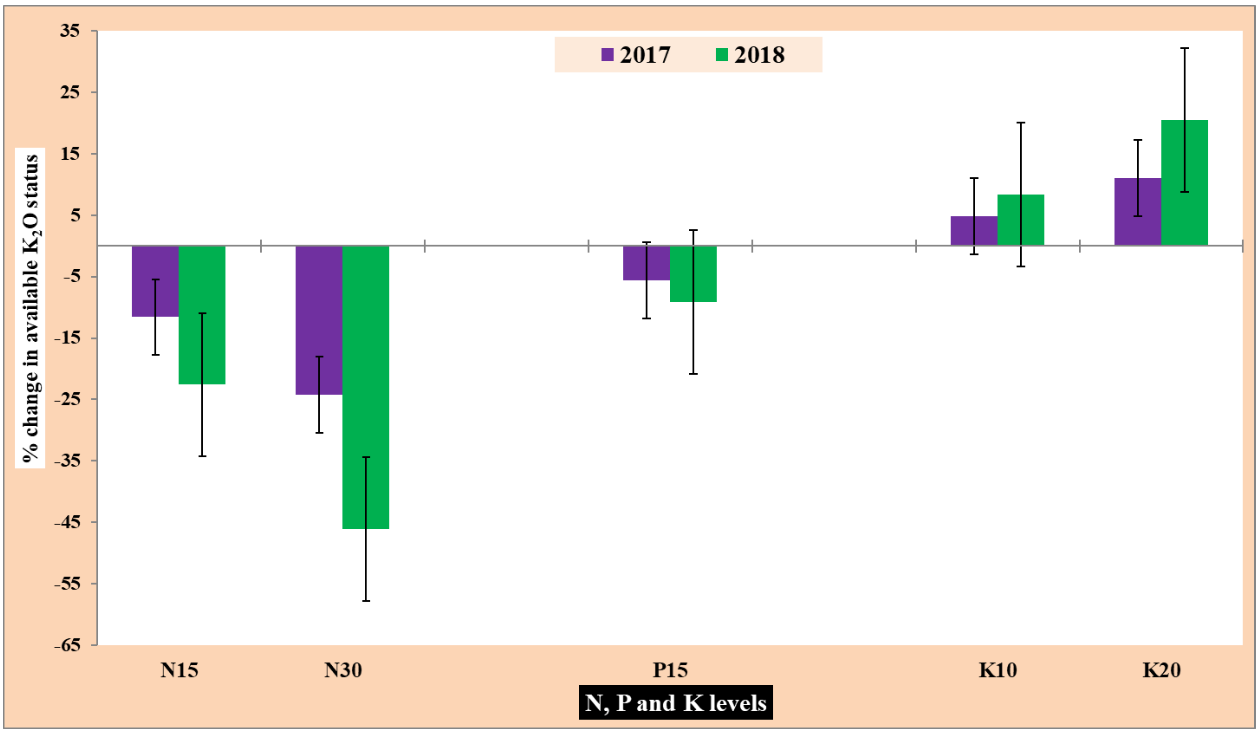

Fig 1: Change in available potassium status (%) in post-harvest soil over respective zero level of NPK during 2017 and 2018

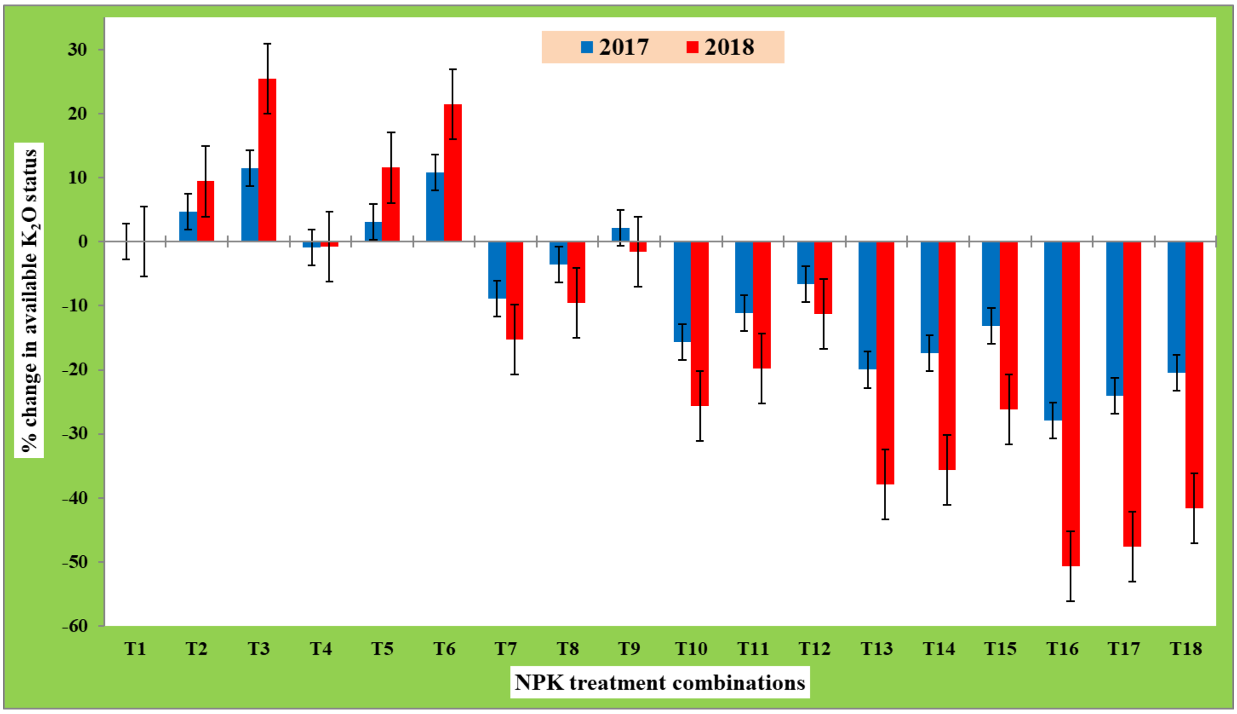

Fig 2: Change in available potassium status (%) in post-harvest soil over absolute control as influenced by NPK levels during 2017 and 2018

Conclusion

The change in available potassium status diminished up to 50% due to application of 30 kg N /ha which had significantly highest reduction among the nitrogen and phosphorous levels. But application of K levels had positively increased available K_2O status from 10 to 20% even though it was not compensating for optimum requirement of foxtail millet. The available potassium gets depleted in the soil up to 50% of its initial content during study of two successive cropping seasons and showed remarkable negative balance in various treatment combinations. There was higher variation between treatment combinations and interactions on all kinds of K-fractions as due to the NPK levels during the course of investigation. Nonexchangeable-K showed least distribution in application of higher levels of N and P fertilizers. The negative-K balance after second crop cycle indicates that crop removal exceeds the potash application up to 55.0 kg K_2O /ha. Thus, it can be noticed that present level of potash fertilization under marginal/infertile Alfisol, soils may start to show potassium deficiency. It is therefore suggested according to removal of potassium by crop plants must be supplement through optimum level to sustain the soil fertility either by crop residue management or potassium fertilization with higher doses to replenish the K-uptake by foxtail millet specially in case of marginal/ infertile Alfisol. The soils of marginal Alfisol lacking in good texture and K-bearing clay minerals at lower soil pH with low buffering capacity which were fails to supply the readily available-K forms.

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